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NASA GRANT NAGW-1916

OPERATION OF THE UNIVERSITY OF HAWAII 2.2M TELESCOPE ON MAUNA KEA

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FINAL REPORT

November 1989–October 1994

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During the period November 1, 1989–October 31, 1993, operation of the University of Hawaii's 2.2-meter telescope was partially funded by grant NAGW-1916 from the NASA Planetary Astronomy Program. This grant was extended until October 31, 1994 by means of a no-cost extension.

During the period Nov 1989–Oct 1993, grant NAGW-1916 provided somewhat less than 20% of the operating budget of the telescope. The remainder was funded by the State of Hawaii, through the University of Hawaii. During this period, the fraction of observing time devoted to studies of solar system objects (e.g., planets, planetary satellites, asteroids, and comets) was approximately 21% (i.e., it exceeded the fractional funding provided by this NASA grant). Proposals for use of the solar system observing time coming from within and outside the University of Hawaii competed for this observing time on an equal basis; applications were judged on scientific merit by a time allocation committee at the University of Hawaii.

TELESCOPE AND INSTRUMENTATION

During the grant period, many very substantial improvements to the telescope and its instrumentation were made. These include:

HIGH RESOLUTION IMAGING AND TIP-TILT SECONDARY:

A new f/31 secondary mirror was acquired (using state funds) in late 1991. The shape of this secondary was specified to match the excellent figure of the primary, and deliver a two-mirror enclosed energy of 80% in 0.2 arcsec (compared to 0.4 arcsec for the f/10 system). A piezo-driven momentum-compensated tip-tilt driver, specially designed for this 8-inch diameter mirror, was purchased (also using state funds) in late 1991. New spiders and a new central hub were designed to support the new mirror and tip-tilt driver, which are mounted on a hexapod mount. A new guider was constructed late in the grant period—this provides the tip-tilt guide signal. Successful tip-tilt guiding was performed in July 1994 for the impact of Comet Shoemaker-Levy 9 with Jupiter.

OPTICAL IMAGING AND SPECTROSCOPY:

At the start of the grant period, the CCD of choice was an 800×800 chip. At the end of the period, the standard detector was a thinned 2048×2048 CCD, with improved control system, lower read noise, and higher QE.

NEAR-INFRARED IMAGING:

At the start of the grant period, a high read-noise HgCdTe 128×128 array was being used. In February 1990, the first high QE, low-noise HgCdTe 256×256 array was used for observations of the dark side of Venus. This remained the IR imager of choice during the until July 1994, when the first 1024×1024 HgCdTe array was used to record the impact of Comet Shoemaker-Levy 9 with Jupiter.

NEAR-INFRARED SPECTROSCOPY:

A near-infrared spectrograph (KSPEC) went into operation on the 2.2-meter telescope in November 1992. This spectrograph has an innovative design which has no moving parts. It utilizes a cross-dispersed echelle design to obtain J, H, and K window spectra *simultaneously* on a 256×256 HgCdTe array, at a resolution of $R \approx 500$. Because the detector has low read-noise and dark-current, this spectrograph is very sensitive—its 10σ limit for continuum detection at 1.6 μm is $H = 12.0$ in 2 minutes. The sensitivity of this instrument has made it ideally suited to studies of faint solar-system objects (such as planetary satellites, asteroids, and comets).

OH SUPPRESSION SPECTROGRAPH:

Engineering tests were performed on an OH suppression spectrograph for the 2.2-meter telescope. This operates in the J and H near-infrared passbands, where atmospheric OH emission is the dominant background. The first part of the instrument is a relatively high-dispersion spectrograph, which images the spectrum onto a mirror which masks out the very narrow OH lines. The light is then recombined, and passes to a lower dispersion spectrograph. So far, OH reduction factors of approximately 20 have been achieved. This instrument promises to be useful for obtaining near-infrared spectra of extremely faint objects, such as very faint asteroids (e.g. 1992 QB1).

OPTICAL SPECTROGRAPHS:

The coudé spectrograph was modernized over the grant period. Major improvements were made to the slit environment, to allow remote setup and guiding. CCDs can be attached to three of the camera systems, and resolutions up to $R \approx 90,000$ can be achieved. Modifications were also made to allow the 256×256 near-infrared camera to be used with the coudé spectrograph. High-resolution spectroscopy continues to be a valuable tool for the study of planetary atmospheres.

A new f/31 spectrograph was built using NSF funding. This spectrograph will be able to make use of the high spatial resolution produced by the tip-tilt secondary and prototype adaptive optics system, allowing high-spatial resolution spectroscopy. The older f/10 Faint Object Spectrograph was also regularly used. Low resolution spectroscopy was also performed with the Wide Field Grism Spectrograph (e.g., a geological investigation of asteroid families).

NEWSLETTER AND DOCUMENTATION:

A newsletter was introduced during the grant period, and was produced every four months, a few weeks before the deadline for receipt of proposals. This newsletter was distributed to all planetary astronomers in the United States who had expressed an interest in receiving it. It was distributed in both electronic form (for speed) and through hardcopy (regular mail). The newsletter contained information about instruments, including their sensitivities, and discussed recent changes and developments at the telescope. A general telescope user manual was produced in 1990. Detailed user manuals were also produced for the major instruments.

GUIDING AND AUTOGUIDING:

The autoguider software was modified to allow guiding at non-sidereal rates (for solar system objects). This has made it possible to take long exposures on faint asteroids and comets.

COMPUTING FACILITIES:

Continuing increases in detector array sizes forced us to upgrade our computational facilities during the grant period. A Supplemental Computing Grant from NASA's Planetary Astronomy Program provided some of the funding for these upgrades. Computers at the summit and at Hale Pohaku are linked by a high-bandwidth fiber-optic link.

SCIENTIFIC HIGHLIGHTS

A sample of the many scientific programs performed on the 2.2-meter telescope during the grant period are described below.

TRANS-NEPTUNIAN OBJECTS AND THE KUIPER BELT:

D. Jewitt and J. Luu discovered the slow moving object 1992 QB1 with the 2.2-meter telescope. This has an orbit which does not cross the orbits of the major planets, and it is the first detected member of a primordial population of trans-Neptunian objects, the so-called Kuiper Belt. There are now 13 identified trans-Neptunian objects. The bulk of these discoveries have been made on the 2.2-meter telescope. Surprisingly, 30–50% of these objects have orbits which are dynamically similar to Pluto.

The steady access to the telescope guaranteed by NASA's support was central to the success of this project.

STUDIES OF DISTANT COMETS:

K. Meech pursued a program of observation of distant comets with the objectives: (i) to search for physical differences in the behavior of the dynamically new comets (those which are entering the solar system for the first time from the Oort cloud) and the periodic comets; and (ii) to interpret these differences, if any, in terms of the physical, chemical nature and the evolutionary histories of the two groups of comets.

CCD observations of comet P/Halley, taken with the UH 2.2m telescope on UT 1991 Feb. 15 showed that the comet had undergone a tremendous brightness outburst near $R = 14.3$ AU. At the time of observation, the comet had a magnitude of $m_R = 20.16$ within a 5" radius aperture (expected nuclear mag = 25.47), and a hemispherical coma extending $> 3 \times 10^5$ km to the southeast. The comet faded considerably by April, and in May all that was visible was a diffuse low surface brightness coma ($\sim$ 26.6 mag/arcsec^2), at least 2×10^5 km in extent; there was no evidence of the nucleus down to a limit of $m_R = 25.5$. The outburst, occurring some time before 14.3 AU is most likely caused by the release of CO from a subsurface chemical inhomogeneity.

OTHER COMETARY STUDIES:

D. Jewitt and J. Chen used data from the 2.2-meter telescope to study the incidence of splitting among short period comets. Their CCD observations confer a substantial advantage for the detection of faint secondary companions to active comets. These observations will provide the first un-biased estimate of the rate of splitting of cometary nuclei. Jewitt and Chen also conducted extensive observations of the split comet Shoemaker-Levy 9.

PLUTO-CHARON SYSTEM:

D. Tholen performed frequent observation of Pluto-Charon mutual events during the early part of the grant period, and obtained additional calibration data after the mutual event series finished. These data have permitted orbital determinations, measurements of the diameters of both bodies, and mapping of surface albedo.

Portions of seven consecutive nights were scheduled for a study of the barycentric wobble of the Pluto-Charon system, done by visiting scientist J. Elliot, graduate student L. Young (MIT), and D. Tholen. A semimajor axis of 19460 ± 58 km and mass ratio of 0.157 ± 0.004 were determined, suggesting Charon density is similar to or greater than Pluto's. This mass ratio is inconsistent with a HST WFPC measurement from a similar program (which suggests than Charon's density is about half that of Pluto); resolution of this difference requires more observations.

NEAR-IR IMAGING OF VENUS DURING GALILEO FLYBY:

After a mammoth effort by many people, a 256×256 near-infrared camera was made ready for the flyby of Venus by the Galileo spacecraft in early February 1990. Despite poor weather, excellent images of the dark-side of Venus were obtained by a team led by W. Sinton. These images were obtained first on the 0.6m telescope, and then on the 2.2m telescope close to the flyby.

GALILEO SUPPORT OBSERVATIONS OF 951 GASPRA:

D. Tholen and J. Goldader obtained Galileo support observations of 951 Gaspra. Astrometric observations (for navigation) and a complete light curve (to determine shape and orientation) were obtained. Observations were also made simultaneously with specially scheduled thermal infrared observations of Gaspra with the IRTF, to determine the albedo.

NEPTUNE:

H. Hammel (MIT) has performed a long term (8 years) monitoring program of Neptune with the 2.2-meter telescope. Among the most recent results was the discovery of an unusual feature in 1993 in the northern hemisphere, which dominated the reflectivity at methane-band wavelengths.